



Earth Gauge

A National Environmental Education Foundation Program

## Mineral Dust and Climate

Atmospheric aerosols are defined as liquid or solid particles suspended in the air. Examples include smoke from wildfires and industrial activities, volcanic ash and the focus of this paper, mineral dust.

### **MINERAL DUST: WHAT, WHERE, WHEN and WHY**

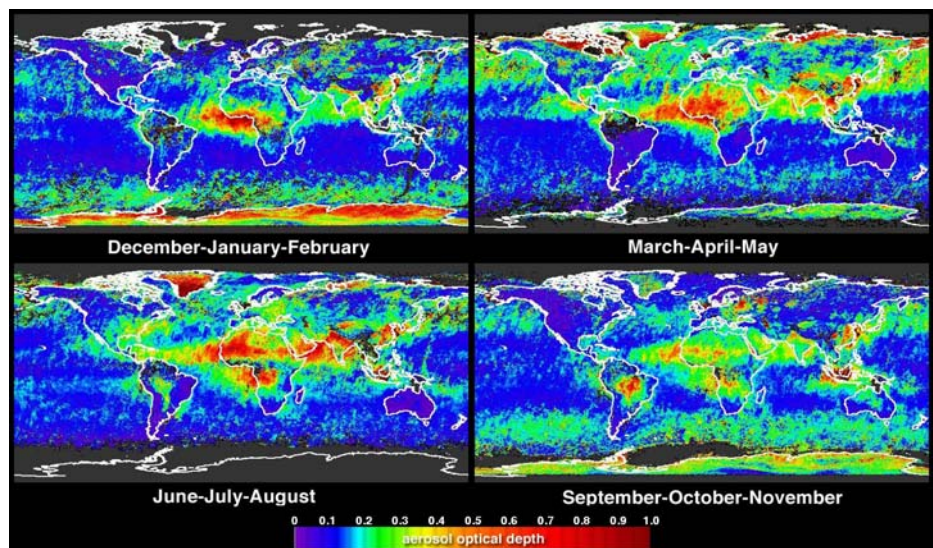
Mineral dust aerosols are soil particles the wind blows into the atmosphere. They are the single largest component of Earth's atmospheric aerosol arsenal, comprising about half of the total aerosol mass. The vast majority of this dust originates in a few discrete "hot spot" regions, including the Lake Chad Basin in North Africa (Earth's largest single source of dust), northwestern China's Taklimakan Desert, parts of Arabia, Iran, the shore of the Caspian Sea, the Lake Eyre Basin in Australia and the area around Utah's Great Salt Lake. All these hot spots sit in low-elevation basins near and often surrounded by mountains, which feed the rivers that deposit large amounts of sediments in these basins. This was especially true during glacial periods, when most of these hot spots were covered by lakes. The ancestor of Utah's Great Salt Lake, Lake Bonneville, which at one point covered about one-third of Utah, is one example. These areas tend to be completely flat, allowing winds to build up momentum and drive more dust into the atmosphere. They also lack significant (or often any) vegetation cover. About half of the dust suspended in Earth's atmosphere originates in North Africa, due to both the abundance of dust sources there and the region's position under the subtropical jet stream, which carries dust around the world.

Ninety-four percent of the planet's dust originates in the Northern Hemisphere. Dust consists mostly of tiny pieces of metal oxides (iron oxide, aluminum oxide, magnesium oxide, etc.), clays and carbonates (such as calcium carbonate or limestone). Just how much dust enters the atmosphere each year is unclear; estimates range from 200 to 5,000 teragrams (Tg, a teragram is one trillion grams), and on average there are about 20 Tg of dust suspended in the atmosphere at any given point in time. This is a rough average, however, as dust emissions show considerable seasonal variability, with maximum emissions during the summer. The interannual variability is less pronounced, although warm North Atlantic Oscillation phases and El Niño events correspond to greater Saharan dust transport across the Atlantic.

The amount of time a dust particle remains in the atmosphere is mostly dependent upon its size, although particle shape also plays a role. Dust particles having radii of between 0.1 and 1.0 micrometers (a micrometer is one-millionth of a meter) have atmospheric lifetimes of 21 days on average. Larger dust particles (between five and 10 micrometers in radius) usually fall out of the sky within 24 hours, and thus do not travel far from their source regions. Dust particles can either fall directly to the Earth (dry deposition) or fall in water droplets (wet deposition). Most dust falls into the oceans, where it becomes a nutrient source.

**Image right:** The seasonal variation in Earth's atmospheric aerosol concentrations. Note the dust plume off the west coast of Africa and how it is transported into the Caribbean during the warm season as the trade winds intensify. Also note the springtime dust plume extending from Asia, over the North Pacific. Image Courtesy of NASA.

[http://eosweb.larc.nasa.gov/HP/DOCS/misr/misr\\_html/global\\_aerosols.html](http://eosweb.larc.nasa.gov/HP/DOCS/misr/misr_html/global_aerosols.html).



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### **MINERAL DUST AFFECTS SURFACE INSOLATION**

Atmospheric mineral dust reduces the amount of sunlight that reaches Earth's surface by absorbing or scattering incoming shortwave radiation as it enters the Earth's atmosphere, sending energy that would be heating the Earth back into space. A measurement called aerosol optical depth (AOD) is used to gauge atmospheric aerosol concentration, with values below 0.1 indicating clear skies and values around 1.0 indicating fairly hazy conditions. Measurements conducted on the Island of Lampedusa in the Mediterranean, where Saharan dust comprises the majority of the aerosols present, indicate that an aerosol optical depth of 0.5 reduces the amount of incoming solar irradiance by about 20 percent with a solar zenith angle (the angle between the sun and the sky directly overhead) of 30 degrees and by about 25 percent at a solar zenith angle of 60 degrees. A larger solar zenith angle means that sunlight must pass through more atmosphere before reaching the Earth's surface, and thus there are more dust molecules for the sunlight to encounter.

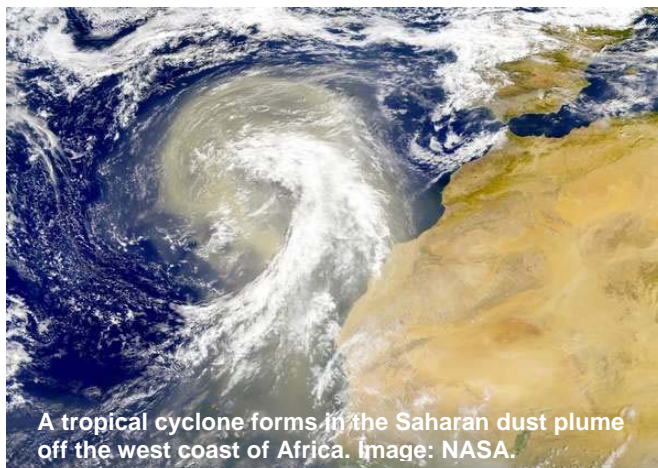


Above: A dust storm near Owens Lake, California.  
Image: UCAR

The proportions of how much energy an individual dust particle will reflect, scatter or absorb and re-emit as longwave energy is dependent upon its mineral composition (different minerals absorb and reflect different proportions of solar radiation), size and shape. Studies conducted in the Indian Desert indicate that cylindrically shaped dust particles absorb more solar energy than spherical objects of equal mass.

### **MINERAL DUST AFFECTS YOU**

- **Drought:** The 1930's Dust Bowl in the central United States was the result of sea-surface temperature induced rainfall reductions amplified by elevated dust concentrations due to decades of conversion of non-erodible prairie to easily erodible cropland. As the land dried, wind erosion increased, as did the average aerosol optical depth, which caused less sunlight to hit the ground, less evaporation and less convective rainfall, forming a positive feedback cycle.
- **Snowmelt:** Major dust storms in America's Southwest cause snowpack in the nearby mountains to become "dirty." This reduces the snow's ability to reflect sunlight, causing it to melt faster. A single dust storm event reduced the albedo of snow cover in the Colorado Rockies from 0.72 to 0.43, nearly doubling the amount of solar energy the snow absorbed. Seventy-five percent of the West's water resources originate from snowmelt. The more readily snow melts in the spring (when the dams are full) the more water must be discharged into the ocean instead of being stored for use during dry summer and fall months.
- **Nutrients:** Mineral dust deposition has been shown to "fertilize" ocean surfaces, potentially stimulating algal blooms, as well as forests such as the Amazon, where between three and four teragrams of Saharan dust are deposited each year. How much this fertilization affects terrestrial and marine ecosystems is debatable.
- **Atlantic Sea Surface Temperatures and Hurricane Season Intensity:** Dust is constantly blowing off the Sahara Desert into the Atlantic Ocean. While the net effect of this "dust plume" on tropical cyclogenesis is unclear, several individual effects include:
  - A reduction in the amount of sunlight that hits the ocean surfaces, resulting in a decrease in ocean surface temperatures. Higher ocean sea surface temperatures have been shown to strengthen hurricanes.
  - When the Saharan Air layer, a layer of dry air that contains the Saharan dust, sits over the Atlantic's main hurricane development region, there is less deep convection and more vertical wind shear, factors that discourage tropical cyclone formation.
  - More dust means more nuclei for cloud formation, a necessary ingredient for tropical cyclone development.



A tropical cyclone forms in the Saharan dust plume off the west coast of Africa. Image: NASA.

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